MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

EEL2216 – CONTROL THEORY

(All sections / Groups)

15 FEBRUARY 2023
2.30p.m. – 4.30p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SEVEN** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) A particular control system is described by a second order differential equation,

$$\frac{d^2y(t)}{dt^2}+6\frac{dy(t)}{dt}+9y(t)=x(t), \qquad x(t)=5u(t)$$

where $u(t)$ is a unit step input function.

(i) Assuming zero initial conditions, find $Y(s)$.

[8 marks]

(ii) Using final value theorem, calculate the final value of $y(t)$.

[2 marks]

(b) In control system, the terms open-loop and closed loop are always used for comparison of stability and output response. In your own words, elaborate the meaning of open-loop and closed-loop system.

[4 marks]

(c) Derive the transfer function $T(s) = C(s)/R(s)$ of the signal flow graph shown in Figure Q1 by using Mason's rule.

[11 marks]

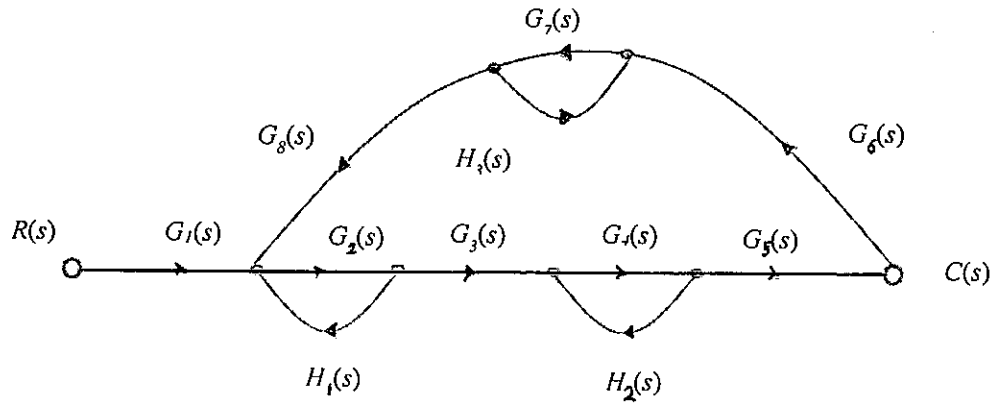

Figure Q1

Continued...

Question 2

(a) Consider a closed-loop transfer function of a unity feedback system is given by

$$G(s) = \frac{7}{s^5 + 2s^4 + 6s^3 + 5s^2 + 7s + 16}$$

(i) Determine the number of closed-loop poles in this system. Use Routh Hurwitz method to find the number of poles on the left-half and right-half of the s-plane. [8 marks]

(ii) Determine the stability of the system. Justify your answer. [2 marks]

(b) Given the block diagram of a unity feedback control system with a forward transfer function $G(s)$:

$$G(s) = \frac{65}{(4s+1)(6s+1)}$$

(i) Determine the error constants (k_p, k_v, k_a). [6 marks]

(ii) Calculate the steady state error for a unit step input $u_s(t)$, unit ramp input $tu_s(t)$, and parabolic input $\frac{t^2}{2}u_s(t)$. [3 marks]

(c) Consider a unity feedback control system shown in Figure Q2.

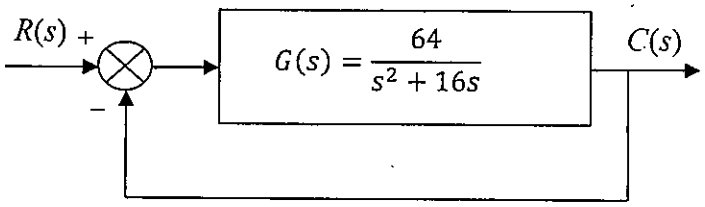

Figure Q2

(i) Calculate the undamped natural frequency and damping ratio. [4 marks]

(ii) Determine whether the system is overdamped, critically damped or underdamped. [2 marks]

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Question 3

(a) A processing plant can be represented by a block diagram as shown in Figure Q3.

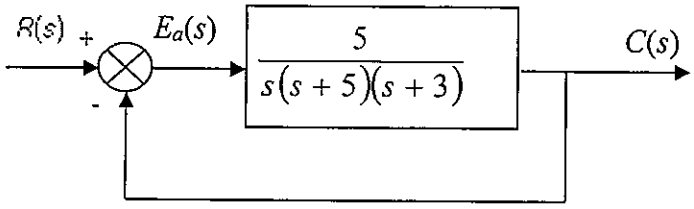

Figure Q3.

(i) Rewrite the loop transfer function and represent it in terms of $j\omega$.

[4 marks]

(ii) Estimate the magnitude response of the loop transfer function.

[2 marks]

(iii) Estimate the phase response of the loop transfer function.

[2 marks]

(iv) Determine the magnitude and phase when $\omega = 0$.

[2 marks]

(v) Determine the magnitude and phase when $\omega = \infty$.

[2 marks]

(vi) Sketch the Nyquist plot.

[5 marks]

(b) Feedback systems are very useful and widely used in amplifier circuits, oscillators, process control systems and electronics systems. As a control engineer, you have to ensure the stability of feedback system. Define the following terms:

(i) Phase crossover frequency
(ii) Resonant frequency
(iii) Phase crossover
(iv) Resonant peak

[8 marks]

Continued...

Question 4

(a) A PID controller is a control loop mechanism employing feedback and is widely used in industrial control systems which requires continuous modulated control. As a control engineer, you are required to compare on the effect of K_P, K_I & K_D to the control system's rise time, overshoot, settling time and steady state error. Summarize your findings in a table, as shown below. Print your answer in answer sheet given.

[9 marks]

	Rise time	Overshoot	Settling time	Steady state error
K_P				
K_I				
K_D				

(b) A controller or compensator is used to regulate a plant system to improve its performance or compensate for the deficient performance of the original system.

(i) Two types of compensators are available, ideal and non-ideal compensator. Elaborate one advantage and one disadvantage of ideal compensator over non-ideal compensator.

[3 marks]

(ii) Describe the main characteristics of a lag-lead controller, Proportional Derivative (PD) controller and Proportional Integral (PI) controller.

[3 marks]

(c) A system with a plant transfer function, $G(s) = \dfrac{1}{s^2 + 8s + 15}$ is shown in Figure Q4.

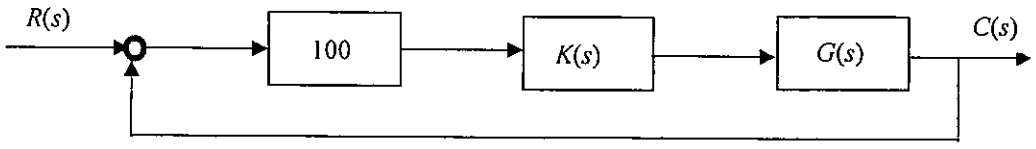

Figure Q4

(i) Given that a PD controller has a transfer function of $K_{PD}(s) = k_a s + k_b$. Design $K(s)$ as a PD controller if the system requires a damping ratio $\zeta = 0.8$ and an angular frequency, $\omega_n = 15$ rad/s .

[6 marks]

(ii) Describe the steps to follow if a control engineer needs to design a PID controller for a single-input single-output system.

[4 marks]

Continued...

Appendix - Laplace Transform Pairs (continued)

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ $(n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
t^n $(n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\ \ (\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper